

**DECADAL SURVEY OF CIVIL AERONAUTICS:
FOUNDATION FOR THE FUTURE**

**Statement of
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Committee on Decadal Survey of Civil Aeronautics
Aeronautics and Space Engineering Board
Division on Engineering and Physical Sciences
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Decadal Survey of Civil Aeronautics: Foundation for the Future

Good afternoon, Mr. Chairman, and members of the committee. Thank you for the opportunity to testify before you today. My name is William Hoover. I am the former executive vice president of the Air Transport Association, and retired from the United States Air Force as a major general. I appear before you today in my capacity as co-chair of the National Research Council's committee on the Decadal Survey of Civil Aeronautics.

The National Research Council is the operating arm of the National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine of the National Academies, chartered by Congress in 1863 to advise the government on matters of science and technology.

In 2005, NASA requested that the National Research Council (NRC) establish the Committee on the Decadal Survey of Civil Aeronautics under the auspices of the Aeronautics and Space Engineering Board. The committee was charged with developing an overarching roadmap for investment in aeronautics research and technology at NASA, and assessing how federal agencies can more effectively address key issues and challenges. Our committee's report was released in June of 2006.

The U.S. air transportation system is a key contributor to the economic vitality, public well-being, and national security of the United States. The next decade of U.S. civil aeronautics research and technology (R&T) development should provide a foundation for achieving four high-priority Strategic Objectives:

- Increase capacity.
- Improve safety and reliability.
- Increase efficiency and performance.
- Reduce energy consumption and environmental impact.

Civil aeronautics R&T should also consider two lower-priority Strategic Objectives:

- Take advantage of synergies with national and homeland security.
- Support the space program.

The purpose of the Decadal Survey of Civil Aeronautics was to develop a foundation for the future—a decadal strategy for the federal government's involvement in civil aeronautics, with a particular emphasis on the National Aeronautics and Space Administration's (NASA's) research portfolio. A quality function deployment (QFD) process was used to identify and rank 89 R&T Challenges in relation to their potential to achieve the six Strategic Objectives listed above.¹ That process produced a list of 51 high-priority R&T Challenges that must be overcome to further the state of the art (see Table 1). These high-priority Challenges are equally divided among five R&T Areas:

- Area A: Aerodynamics and aeroacoustics.

¹QFD is a group decision-making methodology often used in product design.

- Area B: Propulsion and power.
- Area C: Materials and structures.
- Area D: Dynamics, navigation, and control, and avionics.
- Area E: Intelligent and autonomous systems, operations and decision making, human integrated. systems, and networking and communications.

Advances in these Areas would have a significant, long-term impact on civil aeronautics. Accordingly, federal funds, facilities, and staff should be made available to advance the high-priority R&T Challenges in each Area.

Five Common Themes summarize threads of commonality among the 51 high-priority R&T Challenges:

- Physics-based analysis tools to enable analytical capabilities that go far beyond existing modeling and simulation capabilities and reduce the use of empirical approaches.
- Multidisciplinary design tools to integrate high-fidelity analyses with efficient design methods and to accommodate uncertainty, multiple objectives, and large-scale systems.
- Advanced configurations to go beyond the ability of conventional technologies and aircraft to achieve the Strategic Objectives.
- Intelligent and adaptive systems to significantly improve the performance and robustness of aircraft and the air transportation system as a whole.
- Complex interactive systems to better understand the nature of and options for improving the performance of the air transportation system, which is itself a complex interactive system.

These Themes are not an end in themselves; they are a means to an end. Each Theme describes enabling approaches that will contribute to overcoming multiple Challenges in the five R&T Areas. Exploiting the synergies identified in each Common Theme will enable NASA's aeronautics programs to make the most efficient use of available resources.

Even if individual R&T Challenges are successfully overcome, two key barriers must also be addressed before the Strategic Objectives can be accomplished:

- *Certification.* As systems become more complex, methods to ensure that new technologies can be readily applied to certified systems become more difficult to validate. NASA, in cooperation with the FAA, should anticipate the need to certify new technology before its introduction, and it should conduct research on methods to improve both confidence in and the timeliness of certification.
- *Management of change, internal and external.* Changing a complex interactive system such as the air transportation system is becoming more difficult as interactions among the various elements become more complex and the number of internal and external constraints grows. To effectively exploit R&T to achieve the Strategic Objectives, new tools and techniques are required to anticipate and introduce change.

The report also encourages NASA to do the following:

- Create a more balanced split in the allocation of aeronautics R&T funding between in-house research (performed by NASA engineers and technical specialists) and external research (by industry and/or universities). As of January 2006, NASA seemed intent on allocating 93 percent of NASA's aeronautics research funding for in-house use.
- Closely coordinate and cooperate with other public and private organizations to take advantage of advances in cross-cutting technology funded by federal agencies and private industry.
- Develop each new technology to a level of readiness that is appropriate for that technology, given that industry's interest in continuing the development of new technologies varies depending on urgency and expected payoff.
- Invest in research associated with improved ground and flight test facilities and diagnostics, in coordination with the Department of Defense and industry.

The eight recommendations formulated by the steering committee summarize action necessary to properly prioritize civil aeronautics R&T and achieve the relevant Strategic Objectives:

Recommendation 1. NASA should use the 51 Challenges listed in Table 1 as the foundation for the future of NASA's civil aeronautics research program during the next decade.

Recommendation 2. The U.S. government should place a high priority on establishing a *stable* aeronautics R&T plan, with the expectation that the plan will receive sustained funding for a decade or more, as necessary, for activities that are demonstrating satisfactory progress.

Recommendation 3. NASA should use five Common Themes to make the most efficient use of civil aeronautics R&T resources:

- Physics-based analysis tools
- Multidisciplinary design tools
- Advanced configurations
- Intelligent and adaptive systems
- Complex interactive systems

Recommendation 4. NASA should support fundamental research to create the foundations for practical certification standards for new technologies.

Recommendation 5. The U.S. government should align organizational responsibilities as well as develop and implement techniques to improve change management for federal agencies and to assure a safe and cost-effective transition to the air transportation system of the future.

Recommendation 6. NASA should ensure that its civil aeronautics R&T plan features the substantive involvement of universities and industry, including a more balanced allocation of funding between in-house and external organizations than currently exists.

Recommendation 7. NASA should consult with non-NASA researchers to identify the most effective facilities and tools applicable to key aeronautics R&T projects and should facilitate collaborative research to ensure that each project has access to the most appropriate research capabilities, including test facilities; computational models and facilities; and intellectual capital, available from NASA, the Federal Aviation Administration, the Department of Defense, and other interested research organizations in government, industry, and academia.

Recommendation 8. The U.S. government should conduct a high-level review of organizational options for ensuring U.S. leadership in civil aeronautics.

This report should provide a useful foundation for the ongoing effort in the executive branch to develop an aeronautics policy. In addition, even though the scope of this study purposely did not include specific budget recommendations, it should support efforts by Congress to authorize and appropriate the NASA aeronautics budget.

Thank you for the opportunity to testify. I would be happy to take any questions the Committee might have.

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TABLE 1 Fifty-one Highest Priority Research and Technology Challenges for NASA Aeronautics, Prioritized by R&T Area

A Aerodynamics and Aeroacoustics	B Propulsion and Power	C Materials and Structures	D Dynamics, Navigation, and Control, and Avionics	E Intelligent and Autonomous Systems, Operations and Decision Making, Human Integrated Systems, Networking and Communications
<p>A1 Integrated system performance through novel propulsion-airframe integration</p> <p>A2 Aerodynamic performance improvement through transition, boundary layer, and separation control</p> <p>A3 Novel aerodynamic configurations that enable high performance and/or flexible multi-mission aircraft</p> <p>A4a Aerodynamic designs and flow control schemes to reduce aircraft and rotor noise</p> <p>A4b Accuracy of prediction of aerodynamic performance of complex 3D configurations, including improved boundary layer transition and turbulence models and associated design tools</p> <p>A6 Aerodynamics robust to atmospheric disturbances and adverse weather conditions, including icing</p> <p>A7a Aerodynamic configurations to leverage advantages of formation flying</p> <p>A7b Accuracy of wake vortex prediction, and vortex detection and mitigation techniques</p> <p>A9 Aerodynamic performance for V/STOL and ESTOL, including adequate control power</p> <p>A10 Techniques for reducing/mitigating sonic boom through novel aircraft shaping</p> <p>A11 Robust and efficient multidisciplinary design tools</p>	<p>B1a Quiet propulsion systems</p> <p>B1b Ultraclean gas turbine combustors to reduce gaseous and particulate emissions in all flight segments</p> <p>B3 Intelligent engines and mechanical power systems capable of self-diagnosis and reconfiguration between shop visits</p> <p>B4 Improved propulsion system fuel economy</p> <p>B5 Propulsion systems for short takeoff and vertical lift</p> <p>B6a Variable-cycle engines to expand the operating envelope</p> <p>B6b Integrated power and thermal management systems</p> <p>B8 Propulsion systems for supersonic flight</p> <p>B9 High-reliability, high-performance, and high-power-density aircraft electric power systems</p> <p>B10 Combined-cycle hypersonic propulsion systems with mode transition</p>	<p>C1 Integrated vehicle health management</p> <p>C2 Adaptive materials and morphing structures</p> <p>C3 Multidisciplinary analysis, design, and optimization</p> <p>C4 Next-generation polymers and composites</p> <p>C5 Noise prediction and suppression</p> <p>C6a Innovative high-temperature metals and environmental coatings</p> <p>C6b Innovative load suppression, and vibration and aeromechanical stability control</p> <p>C8 Structural innovations for high-speed rotorcraft</p> <p>C9 High-temperature ceramics and coatings</p> <p>C10 Multifunctional materials</p>	<p>D1 Advanced guidance systems</p> <p>D2 Distributed decision making, decision making under uncertainty, and flight path planning and prediction</p> <p>D3 Aerodynamics and vehicle dynamics via closed-loop flow control</p> <p>D4 Intelligent and adaptive flight control techniques</p> <p>D5 Fault tolerant and integrated vehicle health management systems</p> <p>D6 Improved onboard weather systems and tools</p> <p>D7 Advanced communication, navigation, and surveillance technology</p> <p>D8 Human-machine integration</p> <p>D9 Synthetic and enhanced vision systems</p> <p>D10 Safe operation of unmanned air vehicles in the national airspace</p>	<p>E1 Methodologies, tools, and simulation and modeling capabilities to design and evaluate complex interactive systems</p> <p>E2 New concepts and methods of separating, spacing, and sequencing aircraft</p> <p>E3 Appropriate roles of humans and automated systems for separation assurance, including the feasibility and merits of highly automated separation assurance systems</p> <p>E4 Affordable new sensors, system technologies, and procedures to improve the prediction and measurement of wake turbulence</p> <p>E5 Interfaces that ensure effective information sharing and coordination among ground-based and airborne human and machine agents</p> <p>E6 Vulnerability analysis as an integral element in the architecture design and simulations of the air transportation system</p> <p>E7 Adaptive ATM techniques to minimize the impact of weather by taking better advantage of improved probabilistic forecasts</p> <p>E8a Transparent and collaborative decision support systems</p> <p>E8b Using operational and maintenance data to assess leading indicators of safety</p> <p>E8c Interfaces and procedures that support human operators in effective task and attention management</p>